Chapter 3
Tunable RF Front-Ends and Robust Sensing Algorithms for Cognitive Radio Receivers

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ABSTRACT

In this chapter, the concepts of Cognitive Radio (CR) and multi-dimensional spectrum sensing are introduced. Spectrum sensing methodologies, energy efficiency consideration, resources scheduling, and self-management and learning mechanisms in cognitive radio networks are also discussed. The entailed challenges of CR RF front-end architectures are looked into. The synthesis and design performance analysis of a tunable RF front-end sensing receiver for CR applications are presented. The chapter also discusses how sensing performance degradation, which is due to RF impairments, is analytically evaluated. Spectrum sensing algorithms that correct imperfect RF issues by compensating induced error effects through digital baseband processing are also illustrated.

INTRODUCTION

Cognitive Radio (CR), by which a wireless device can sense the radio environment and use unoccupied frequency bands, is thought of as a drastic solution to the increasing demand for efficient radio frequency (RF) spectrum management, and the use of this spectrum by RF devices with limited resources, such as energy and access rights. The solution offered by cognitive radio relies on its capability to observe whether a specific frequency band is occupied or not, and to use an unoccupied band, called a white space.
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(WS), without interfering with the operation of other wireless devices, especially those of authorized or primary users (PUs). Furthermore, if an authorized terminal starts transmission in a WS occupied by a secondary user, the terminal of the secondary user (SU) jumps into a new WS, or stays in the same WS but alters its transmission power level or modulation scheme, to suppress interference.

A survey of spectrum sensing methodologies for cognitive radio is presented by (Yucek, 2009). Besides studying the various aspects of spectrum sensing problem, and their associated challenges, multidimensional spectrum sensing concept is introduced. Herein, the spectrum sensing term is declared as a general term that involves obtaining the spectrum usage characteristics across multiple dimensions such as time, space, frequency, and code. It is not only based on measuring the spectral content, or measuring the radio frequency energy over the spectrum, as traditionally understood. The conventional definition of the spectrum opportunity, which is often defined as a band of frequencies that are not being used by the primary user of that band at a particular time in a particular geographic area, only exploits the frequency, time, and space dimensions of the spectrum. However, other dimensions, such as location, angle of arrival, and code need to be explored. For the location dimension, the spectrum can be available in some parts of the geographical area while it is occupied in others. With the knowledge of the location or direction of primary users, secondary ones can alter their transmission direction without creating any interference. Simultaneous transmission without interfering with primary terminals would be possible in code domain upon using orthogonal coding schemes. The radio space with the introduced dimensions can be defined as a theoretical hyperspace occupied by radio signals, which has dimensions of location, angle of arrival, frequency, time, and possibly others.

The most common spectrum sensing techniques in the cognitive radio literature are given by (Axell 2010, Kwan 2012, Weifang 2009, Yucek, 2009). These include energy detector, waveform-, cyclostationarity-, radio identification, matched-filtering, and sub-sampling based sensing techniques. The selection of a specific sensing method depends on several factors such as required accuracy, sensing duration, computational complexity, and network requirements, thus tradeoffs should be considered. Cooperative sensing, whether it is centralized or distributed, is also proposed by (Yucek, 2009, Axell, 2010), as a solution to problems that arise in spectrum sensing due to noise uncertainty, fading, and shadowing. However, energy efficiency in cooperative cognitive radio networks has to be considered. The energy consumption of such networks increases as the number of cooperating users grows. Hence, techniques such as on-off sensing and censoring have been developed to improve the energy efficiency in cognitive radio networks. The implementation of a reconfigurable cognitive sensing methodology is exemplified by (Weingart, 2007). It may adjust itself in a manner that highly minimizes the probabilities of misdetection and false alarm to meet performance goals. Although this would be an optimum solution of the spectrum sensing problem, it is worth mentioning here that other challenges such as high sampling rate, high resolution analogue to digital converters (ADCs) with large dynamic range, and high speed signal processors are demanding associated requirements with spectrum sensing. On the other hand, RF receivers are expected to process narrowband baseband signals of the wide frequency spectrum with reasonably low complexity and low power processors. In other words, the RF components such as antennas, amplifiers, mixers and oscillators are expected to operate over a wide range of frequencies, as reported by (Yucek, 2009, Cabric, 2005).

Spectrum mobility, channel sensing, resource allocation, and spectrum sharing are important functional cognitive radio stimuli, which are exploited by Medium Access Control (MAC) protocols. The design of cognitive MAC protocols is still open to research and investigation according to (De Domenico, 2012). It aims to build up a spectrum opportunity map, schedule available resources, improve coexistence